Year 2 Report
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A Gulf Coast Monitoring and Hazards Decision Support Tool – Enhancements Using NASA Earth Science Products, Data and Models

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The goal of this NASA funded project is to integrate NASA Earth science results into the WAVCIS decision support system that presently serves environmental resource and emergency management and response mainly for the Louisiana coastal region (Figure 1). NASA results and model outputs will be extended to a larger coastal region that will include the states of Mississippi and part of Texas coast into an enhanced DSS that will include a web-based portal (the Gulf Coast Information System). The project will use the outputs of a coastal predictive model, and data/products from satellite observations such as MODIS Aqua/Terra, QuikSCAT, and Jason. The project will evaluate, verify, validate and benchmark these NASA measurements and work to extend and use the results with partners such as MMS and LDNR and other users.
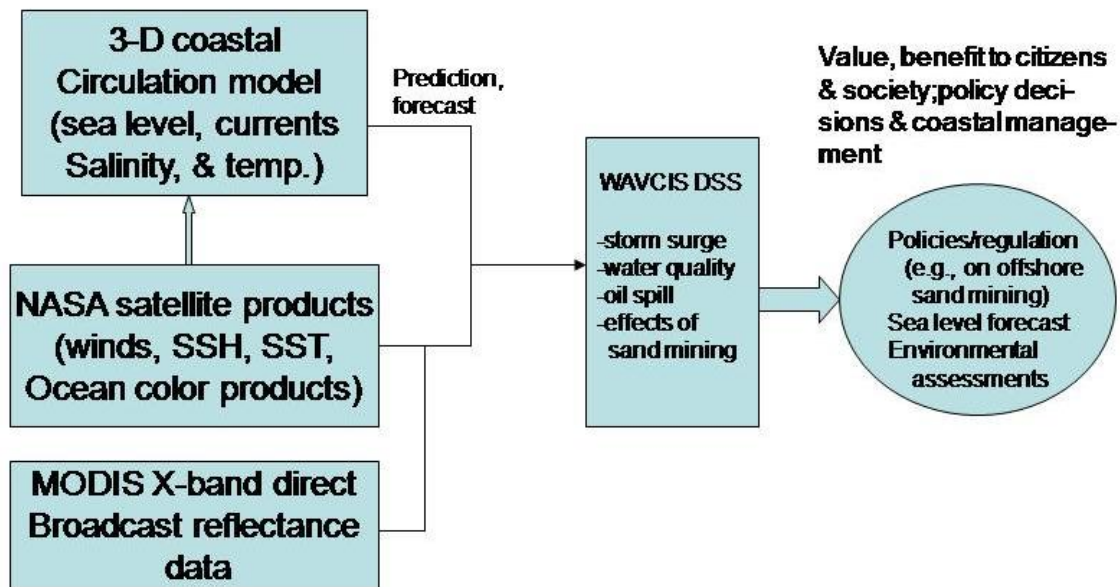

Figure 1. Integrated Systems Solution Chart for the enhanced DSS.

KEY ACTIVITIES CONDUCTED DURING THE YEAR

1. DSS Website and Server Development Work
    The development of the Gulf Coast Information System DSS website (**http://gulf-coast.lsu.edu**) has continued during year 2 of the project. This website has a link to the WAVCIS site while a link on the WAVCIS site provides access to the NASA remote sensing data, products and model outputs on the Gulf Coast Information System site. Additional NASA products were generated through software development using IDL and software based on the NASA SeaDAS package. These include: i) High resolution 250 m MODIS true color imagery, ii) high resolution MODIS normalized vegetation index (NDVI) for coastal region of Mississippi, Louisiana and eastern part of Texas, iii) Dissolved organic matter (CDOM) and suspended particulate matter (SPM) products for SeaWiFS satellite ocean color data were derived using regional optimized algorithms (D'Sa et al. 2003; 2006; 2007; 2008). The CDOM and SPM products are being generated using data downloaded from NASA DAAC and include archived products (from 1999) that will be available to users. These and other NASA derived data and products such as i) MODIS Aqua/Terra SST and Chlorophyll, ii) high resolution (12.5 km) QuikSCAT wind speed and direction, iii) Jason-1 sea surface height anomaly along-track and interpolated data are presently available online at http://gulf-coast.lsu.edu. Geographical Information System (GIS) capability has been added to the website for serving high resolution processed Landsat imagery of the coastal region of Mississippi and Louisiana. Presently selected Landsat imagery are being served using Google Earth (http://gulf-coast.lsu.edu/GIS.html) and open source MapServer (http://gulf-coast.lsu.edu/cgi-bin/landsat5tm_la-south_lsu_2005.py) GIS software developed for the project to enhance user interaction with satellite data. Near real-time and forecast NCOM model outputs are being generated daily and being made available on the website (http://gulf-coast.lsu.edu/CoastModel.html). Verification and Validation (V & V) of various datasets and products have been and are being conducted during Year 2 of the project and will be described in the following sections.

2. MODIS High Resolution (250 m) True Color Imagery

Figure 2. MODIS 250 m high resolution true color imagery derived from three high spatial resolution bands following the passage of hurricane Gustav in September 2008.

The high resolution MODIS true color imagery are being processed and will be generated (e.g., Figure 2) for the study area (coastal Mississippi, Louisiana and Texas) using the 250 and 500 m bands from MODIS sensor. An example shown in Figure 2 indicates suspended sediments following the passage of Hurricane Gustav in September 2008. The image clearly demonstrates the extent of resuspension that extended from the Mississippi River to the east all the way to Galveston where the hurricane made landfall.

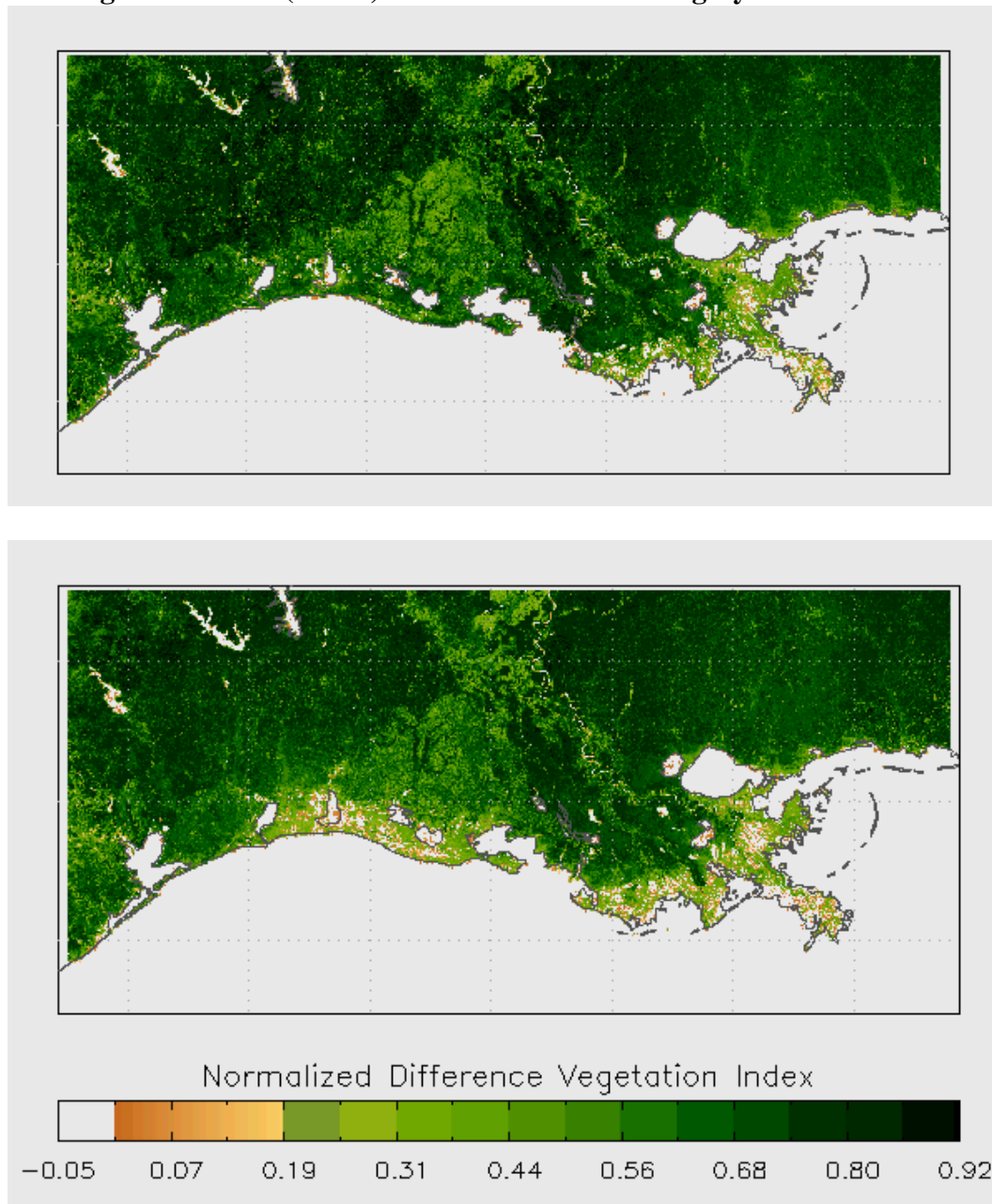## 3. MODIS High Resolution (250 m) NDVI Product and Imagery

Figure 3. Normalized Difference Vegetation Index obtained from MODIS 250 m resolution bands that are cloud free derived over a 16-day interval before and after the passage of Hurricane Rita in 2005.

The Gulf coast comprising the states of Mississippi, Louisiana and Texas is a region that has been impacted strongly by hurricanes in the last few years. The low-lying coastal region in these states have been adversely affected by winds and storm surge that have flooded extensive inland coastal areas. Software programs have been adapted and written to process MODIS 250 m resolution data downloaded from LP DAAC (Land Processes Distributed Active Archive Center) after have been masked for clouds, water and aerosols. Example in Figure 3 shows the adverse effect of Hurricane Rita on the Louisiana coastal vegetation.

4. MODIS (Aqua and Terra) Sea Surface Temperature (SST) and Product Analysis
4.1 MODIS SST product
 SST imagery from MODIS Aqua and Terra satellite sensors at 1 km spatial resolution are served on the Gulf-Coast Information System website and include both daily updates of SST imagery as well as archive imagery from 2002 (Figure 4). SST imagery is provided for the whole Gulf of Mexico, while an expanded view of the study area is available by clicking on the study area (rectangular inset) comprising of the coastal waters extending from Mississippi to Texas (Figure 4). MODIS is a 36-channel sensor sensitive to visible and infrared (IR) wavebands carried by the Terra and Aqua satellites. The orbits of these two satellites are timed so that Terra travels from north to south across the equator in the morning, while Aqua travels from south to north in the afternoon. Terra was launched on December 18, 1999, and passes over the Gulf of Mexico twice daily around 4:00 (nighttime) and 17:00 (daytime). Aqua, launched on May 4, 2002, passes the Gulf of Mexico twice daily around 8:00 (nighttime) and 19:00 (daytime). While visible and near-IR channels of MODIS are used for ocean color measurements (e. g. chlorophyll concentration), thermal-IR channels ($3.6-12.3\mu m$) are intended primarily for sea surface temperature (SST) measurements. Both day and night SST imagery are made available to user from both the satellite sensors (Figure 4).
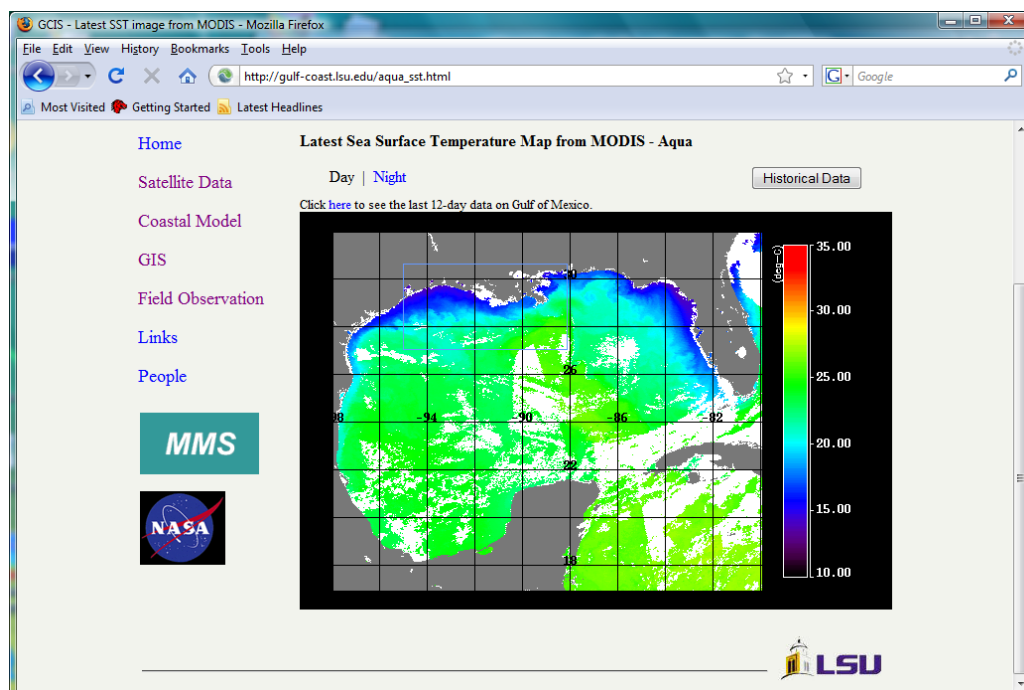

Figure 4. MODIS SST imagery (Aqua) for the Gulf of Mexico being served on the GCIS website. Inset (rectangular box) allows for an expanded view of the study area.

4.2 MODIS SST V&V

We have conducted an extensive V&V of the MODIS Sea Surface Temperature (SST) product for the Gulf of Mexico by comparing satellite estimates with field data from the WAVCIS monitoring stations (Figure 5) and NDBC buoys (Figure 6). The MODIS level-2 sea surface temperature (SST) products from Terra and Aqua satellites distributed by NASA were compared with in-situ measurements in the Gulf of Mexico between 2002 and 2006. While SST derived from daytime-Terra data or the nighttime-Aqua data are found to be in excellent agreements with the in-situ measurements, SST derived from nighttime-Terra data or the daytime-Aqua data show significant discrepancies from the in-situ measurements. These preliminary results probably suggest some issues in the SST processing algorithm that is being examined further.
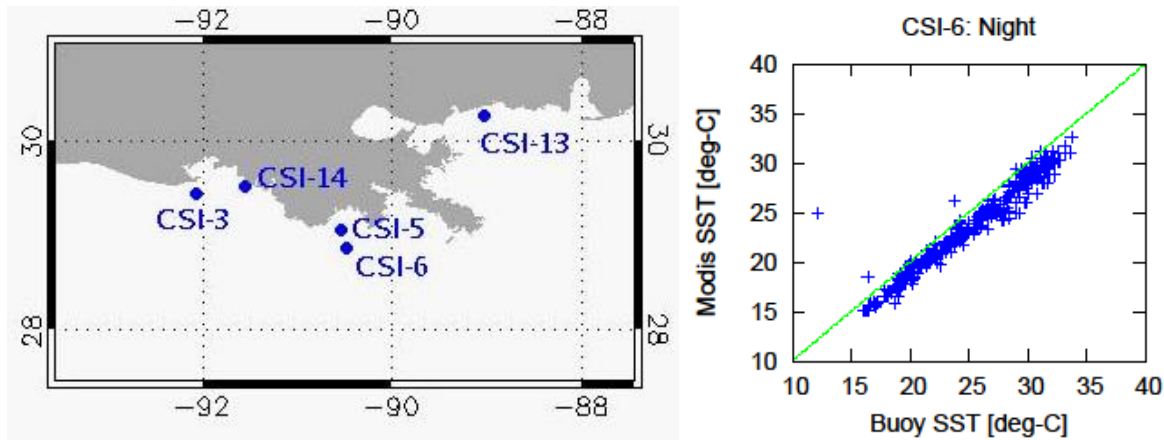

Figure 5. (Left panel) Location of WAVCIS stations used for validation of MODIS SST data for the period 2002 to 2006.
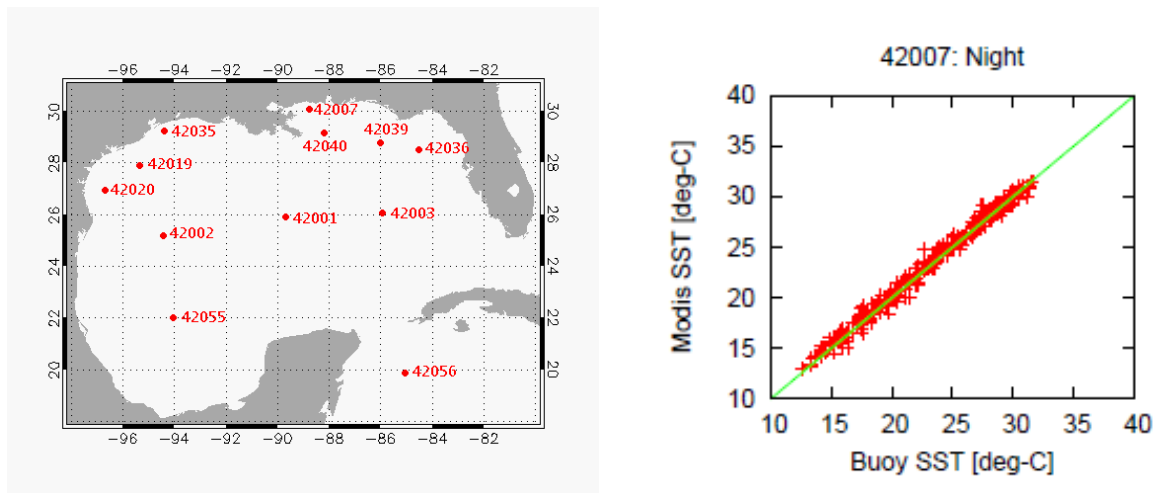

Figure 6. (Left panel) shows the location of the NDBC buoys in the Gulf of Mexico. (Right panel) shows the comparison of coincident SST obtained from NDBC buoy 42007 located off the Mississippi coast versus MODIS Aqua (nighttime) SST over a four year period from 2002 to 2006.

4.3 EOF Analysis of MODIS SST images for the northern Gulf of Mexico
Empirical orthogonal function (EOF) analysis of MODIS SST data from 2003 to 2008 were performed that indicated surface SST spatial and temporal evolution and the potential factors such as winds, river discharge influencing its variability in the study area (Figure 7). The first mode is 5.7% of the total variance and has an annual periodicity. The second mode is 2.7% and third mode 2.4% (not shown), respectively of the total variance and are not very periodic. Further analysis of this statistical method is ongoing towards submission to a peer-reviewed publication.
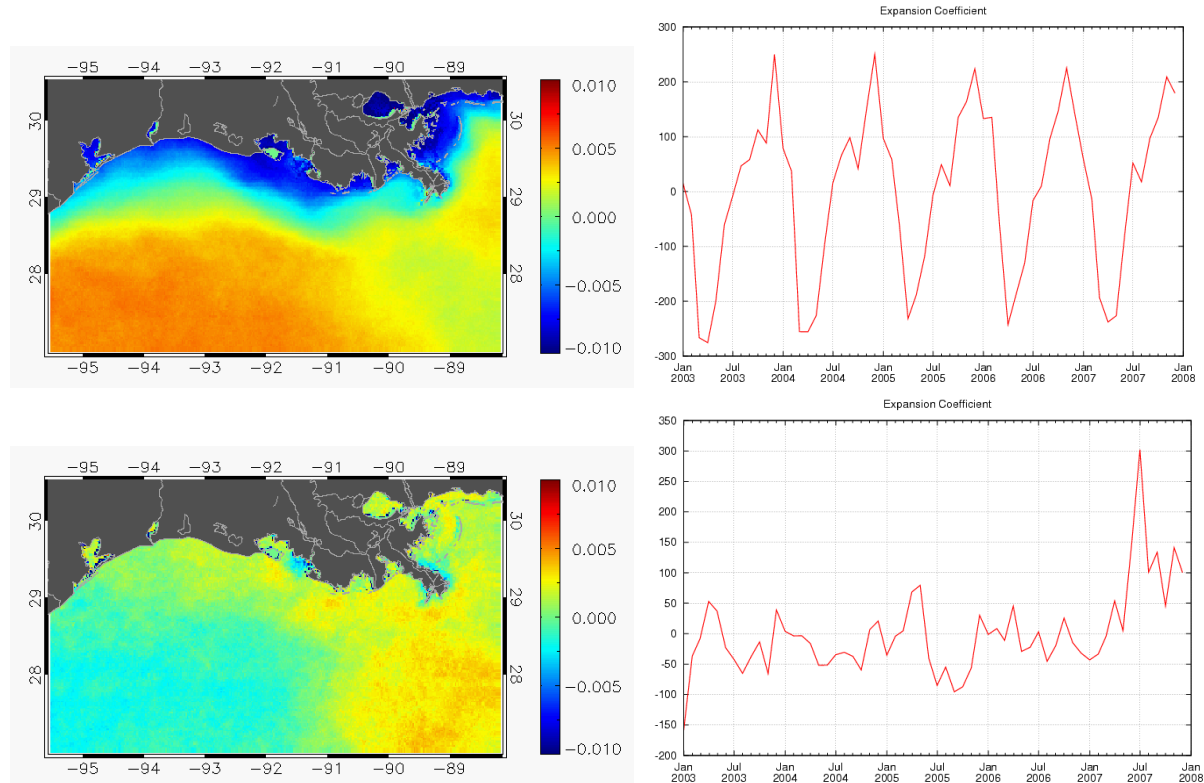

Figure 7. Empirical orthogonal function analysis (EOF) of the study area showing (top panel) the first principal component (spatial mode) (left panel) and its expansion coefficient (left panel) for the period 2002-2008. Corresponding second principal component and its expansion coefficient are shown in the bottom panel.

5. MODIS and SeaWIFS Ocean color Products
5.1 MODIS Chlorophyll Concentration (Aqua) and product analysis
MODIS data from Aqua and Terra satellites are downloaded from DAAC daily and chlorophyll concentration (mg m^{-3}) generated for the Gulf of Mexico region (Figure 8). Clicking on the image within the study area provides an expanded view of the chlorophyll distribution. The daily high resolution (1 km) surface chlorophyll estimates is intended to provide short-term information on ocean color variability that is applicable for monitoring the river dominated coastal environment. The latest 12-day chlorophyll imagery is provided on the DSS website. This temporal and spatial coverage would be useful for event monitoring during frontal passages or hurricanes.
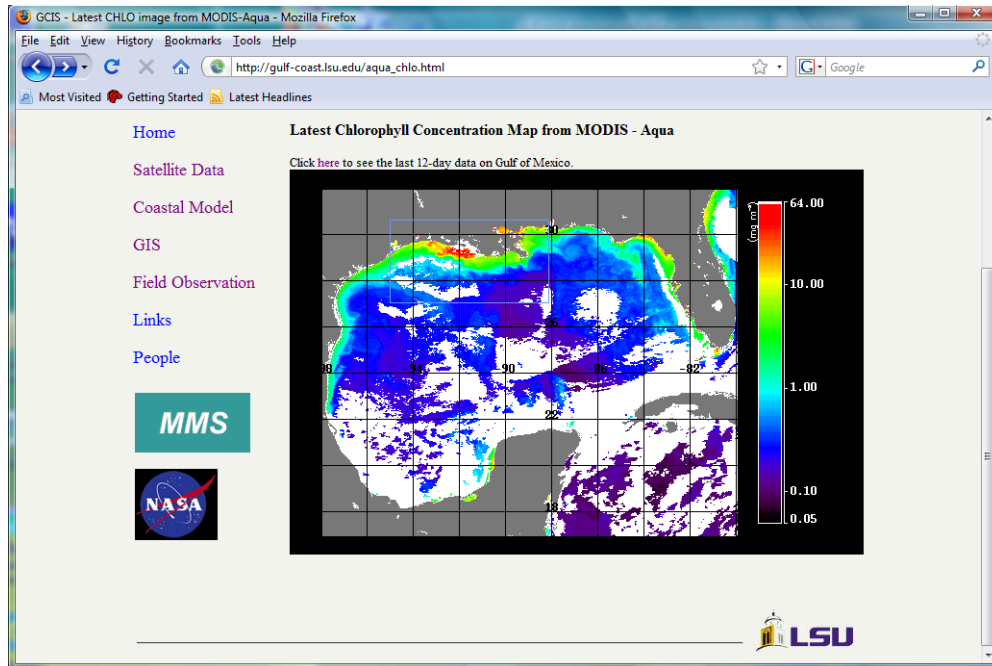
Figure 8. Latest MODIS 1 km surface chlorophyll imagery available on the DSS website. Inset rectangle provides an expanded view of the study area.

5.2 Empirical Orthogonal Function (EOF) analysis of SeaWiFS Chlorophyll of the study region
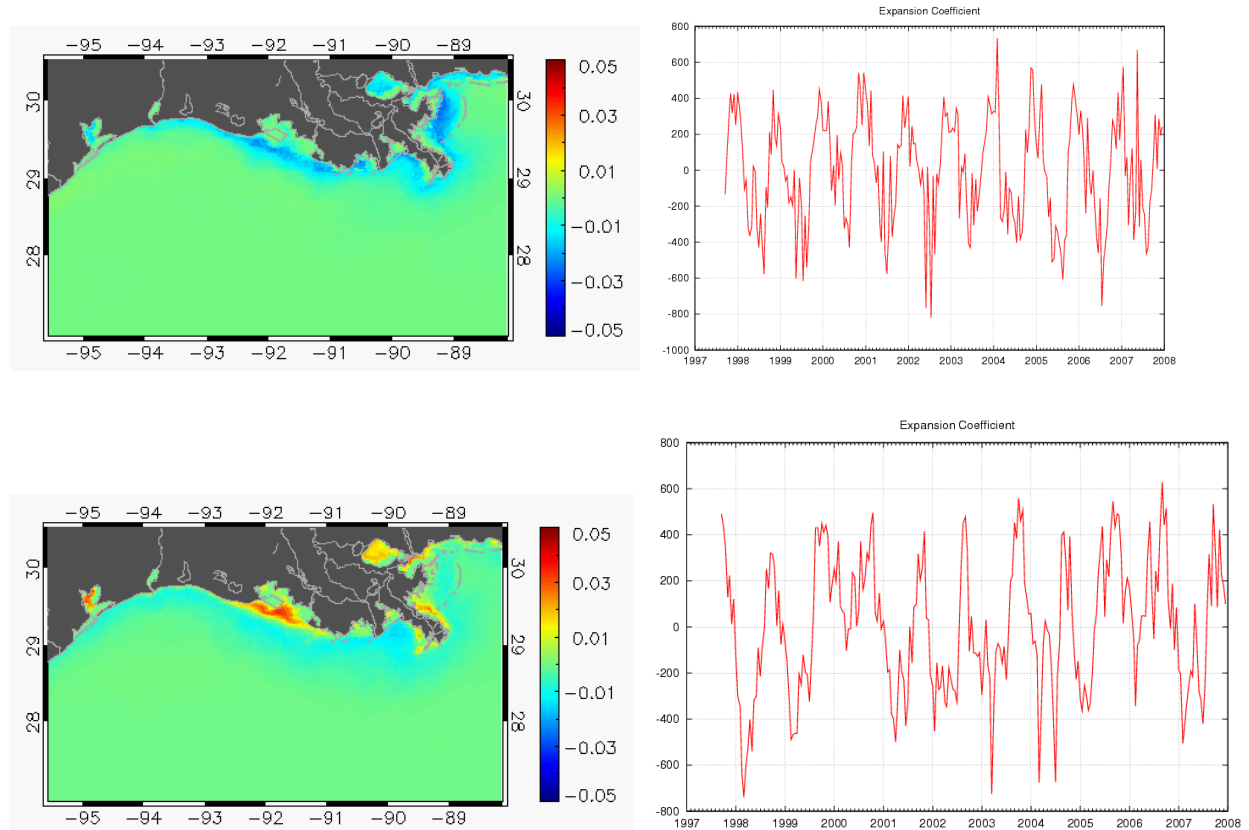

Figure 9. First (top panel) and second (bottom panel) modes EOF analysis along with their expansion coefficients (right panels).

An analysis of MODIS surface chlorophyll of the study area (between 88.5-95.5º W and 27-30.5º N) was conducted from 2002 to 2008 using time-series satellite data to study seasonal and interannual variability. The use of an empirical orthogonal function analysis revealed some principal factors associated with the variability and helped identify seasonality in the data (Figure 9) and is being further used in combination with wavelet analysis (not shown) to examine statistical correlations in the data and the environmental forcing.

5.3 SeaWiFS ocean color products: CDOM and SPM products
Colored dissolved organic matter (CDOM) and suspended particulate matter (SPM) are important water quality parameters of interest to decision makers. These products are of significant interest to the DSS partners (LDNR-Louisiana Department of Natural Resources) and MMS especially in combination with WAVCIS field wave data. However, due to the optical complexity of water-leaving radiance signals in large river-dominated coastal waters standard ocean color algorithms often do not perform accurately in these waters necessitating the need to fine tune or develop regional algorithms. The PI has processed and analyzed optical data sets from field cruises in the northern Gulf of Mexico waters influenced by the Mississippi and Atchafalaya rivers. These data sets were analyzed and results were submitted for publication in peer-reviewed journals that include new empirical algorithms for both CDOM and SPM for SeaWiFS satellite data. We have applied a regional CDOM algorithm to SeaWiFS imagery and processed time-series data that is presently available on the DSS website as CDOM absorption imagery (Figure 10) of the study area.
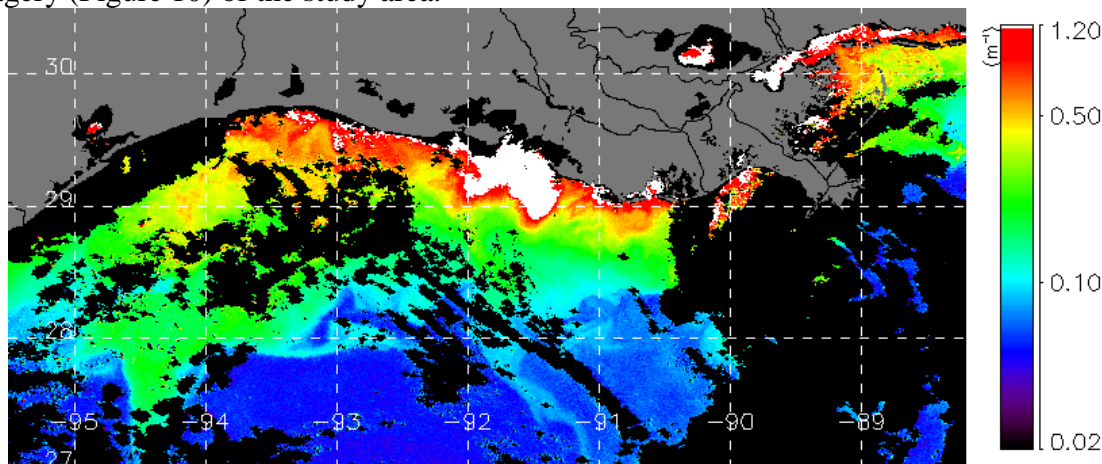

Figure 10. CDOM absorption at 412 nm derived from SeaWiFS imagery of 29 September 2005 showing the strong impact of CDOM distribution following hurricane Rita in September 2005.

We have also applied a new regional SPM algorithm (D'Sa et al. 2007, Geophysical Research Letters) to SeaWiFS imagery of the study area to provide daily (Figure 11) and long-term estimates of SPM on the DSS website. We have written IDL code to implement the regional algorithms and generated long-term SPM time-series for the northern Gulf of Mexico. SPM data is a particularly useful product to support users such as MMS and LDNR who are interested in using offshsore sand resources for coastal restoration. Following hurricane Gustav in 2008, Texas General Land Office in a presentation at a recent MMS Technical Workshop has indicated that offshore sand resources off Texas would be needed for coastal restoration following extensive erosion along the eastern Texas coast due to Hurricane Gustav.
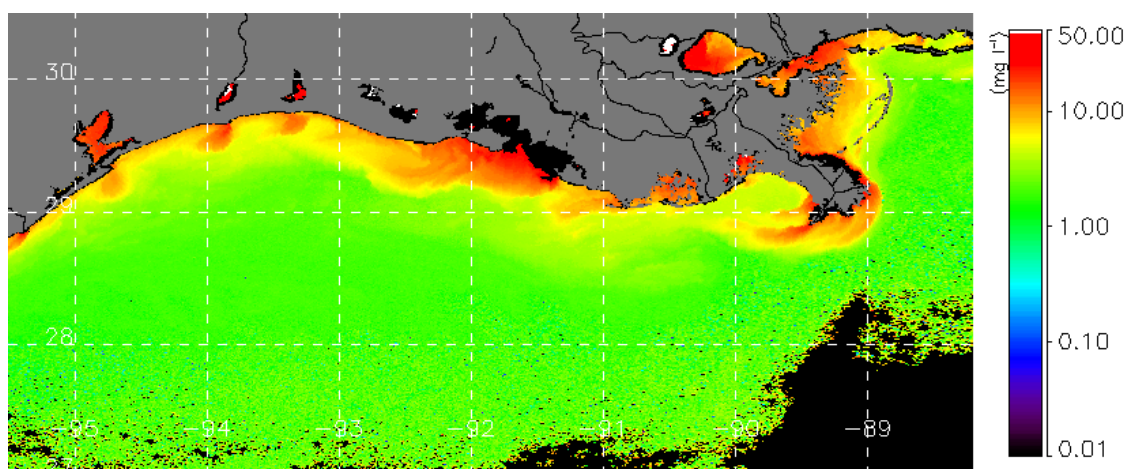
Figure 11. SPM estimates (mg m^{-3}) derived from SeaWiFS data of 25 January 2007. Strong sediment plumes associated with river discharge is observed off the Mississippi and Atchafalaya rivers.

6. QuikSCAT High Resolution (12.5 km) Wind Speed/Direction Product and V & V

We have started posting the latest L3 wind data from Seawinds/QuikSCAT satellite. The data are downloaded from PO.DAAC every day processed on our computer and posted on the website (Figure 12). Users can also display QuikSCAT data from historical image archives since July 1999 to present.
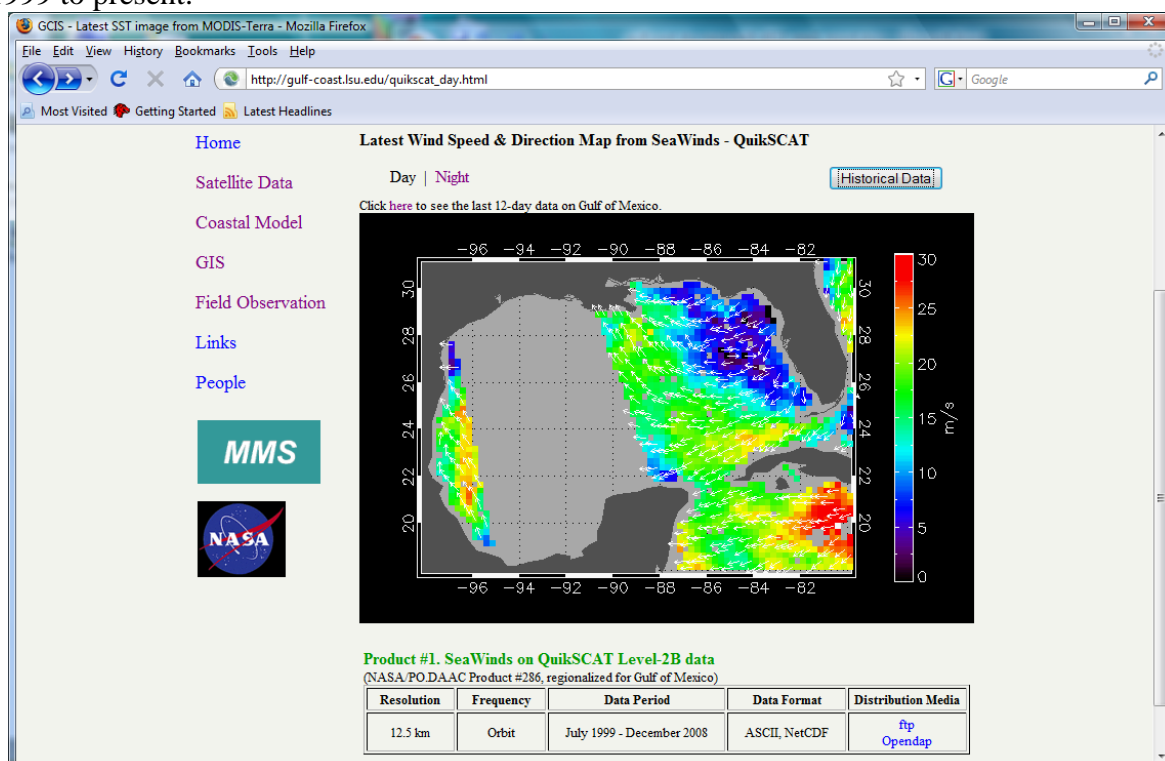

Figure 12. Latest 12.5 km resolution QuikSCAT wind speed and direction data made available on the DSS website for the Gulf of Mexico. Processed wind data is also available for download through the ftp and and Opendap servers.
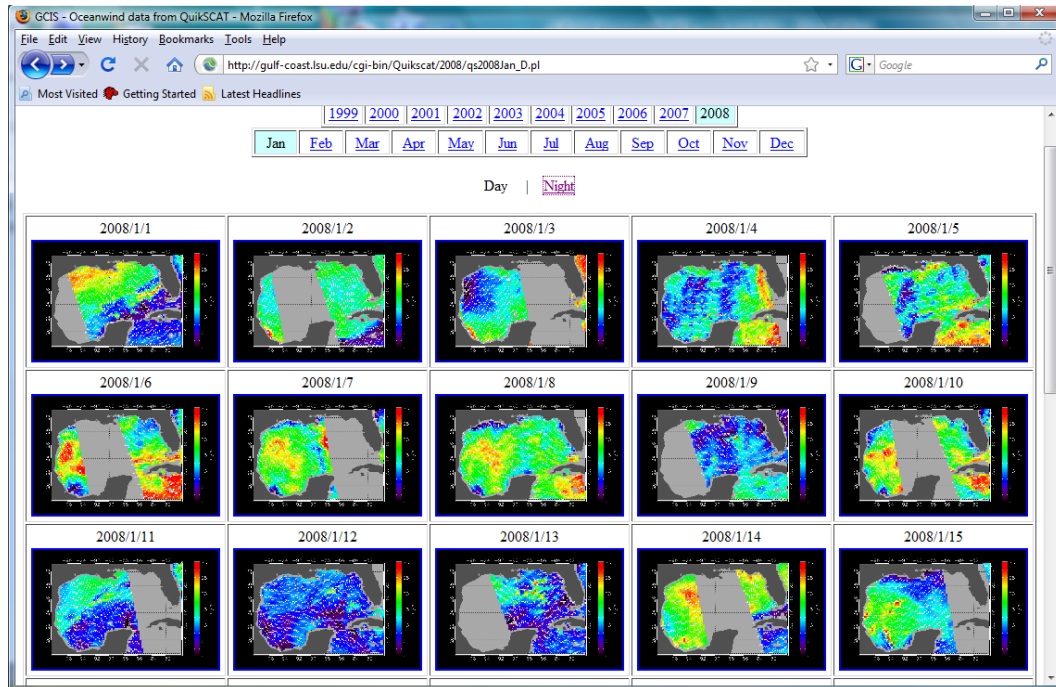
Figure 13. Archived QuikSCAT wind data from 1999 is also made available on the DSS website.

6.1 V&V of QuikSCAT wind products

We have conducted a long-term V&V study (January 2005 - February 2007) of the various QuikSCAT wind products from DAAC (JPL) for the Gulf of Mexico. These products include the Level 3B 25 km gridded, and the latest Level 2B 12.5 km swath DIRTH and NWP products. Comparisons of the QuikSCAT wind data were made against nearshore and offshore buoys located in the Gulf of Mexico.
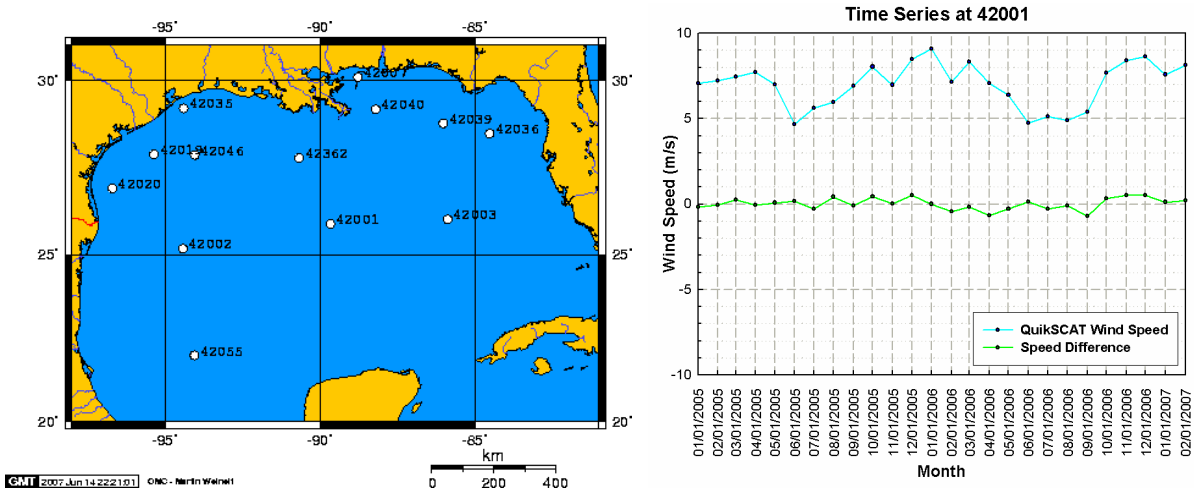

Figure 14. QuikSCAT wind data were validated against buoy wind measurements at various locations in the Gulf of Mexico. The locations of the buoys are shown on the left panel of the figure. (Right panel) Time series of monthly averaged QuikSCAT wind speed at buoy 42001 shown as a line plot to depict seasonal variations. Also shown is the difference in speed between QuikSCAT and buoy measurements.

Results from these analyses suggest that the latest 12.5 km DIRTH product provides the best performance among all the QuikSCAT products (Sharma and D'Sa 2008). However, we do observe degraded performance of the product at locations very close to the coast. Based on these results we have further evaluated the performance of the L2B DIRTH and buoy wind data during hurricanes in the Gulf of Mexico for the period 2002-2006. Results suggest that the Level 2B DIRTH wind product is at par or better than NDBC buoys during hurricanes (Sharma and D'Sa 2008).
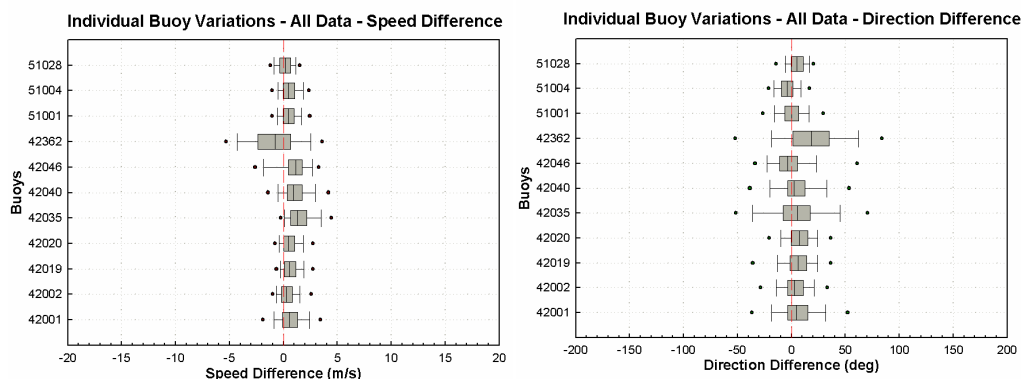

Figure 15. Variations between QuikSCAT and buoys in the Gulf of Mexico and three buoys (51001, 5104 and 51028) in the Pacific (shown for comparison). The x-axis is the difference between QuikSCAT and buoy measurements. The edges of the boxes depict the 25th and 75th percentile. The central line denotes the median. The error bars beyond the box depict the 10th and 90th percentile and the points depict the 5th and 95th percentile.

7. Jason-1 Sea Surface Height (SSH) data and Product V&V in the Gulf of Mexico
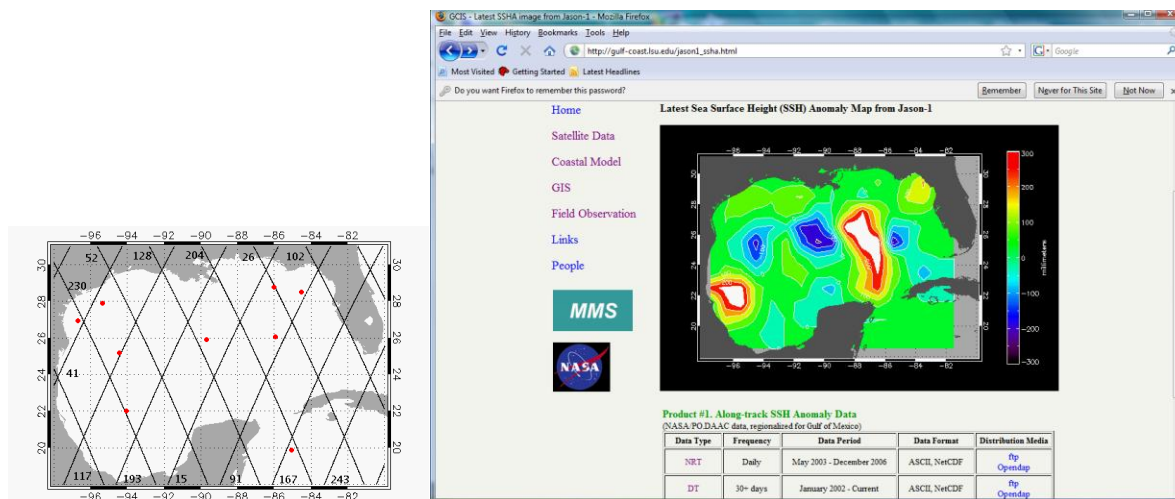

Figure 16. (Left panel) The tracks of Jason-1 in the Gulf of Mexico along with the location of buoys used for validation of Jason-1 products. (Right panel) Website display and distribution of interpolated SSHA for the Gulf of Mexico.

Sea Surface Height Anomaly (SSHA) data from Jason-1 satellite are downloaded from PO.DAAC as soon as it is becomes available. There is approximately 30-day latency in this product at PO.DAAC with the Jason-1 tracks for the Gulf of Mexico shown in Figure 16 (left panel). In addition to the along-track data localized for the Gulf of Mexico region, we also display the map of SSHA at our website which is generated from along-track data by a simple interpolation (Figure 17). The SSHA data is available through ftp and Opendap servers for online distribution and users can download and examine any archived cycle for the Gulf of Mexico.
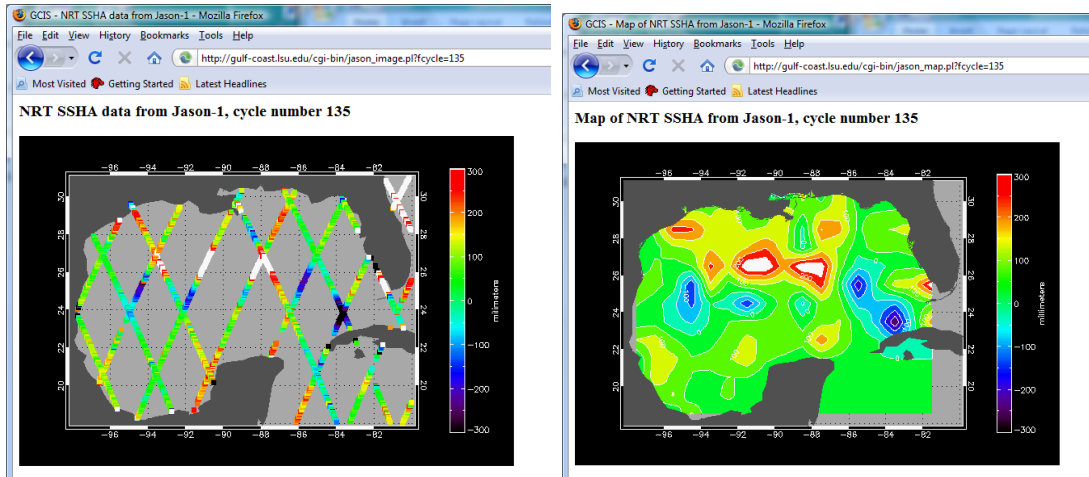

Figure 17. (Left panel) Jason-1 along-tracks for ascending and descending passes during one 10-day cycle for the Gulf of Mexico. (Right panel) Jason-1 SSHA map of the Gulf of Mexico obtained by interpolation of along-track SSHA during cycle 1 (15-24 January, 2002).

7.1 V&V of Jason-1 Significant Wave Height (SWHT) product

We have also examined the significant wave height (SWHT) data product from Jason-1 satellite. The SWHT data from Jason-1 satellite over the duration of 183 cycles (January 2002 to December 2006) were compared with the in-situ measurements at 9 nearshore and offshore buoys in the Gulf of Mexico. The Jason-1 data are collocated with the buoys and averaged inside the radius of 10 – 150 km, depending on the distance between a buoy and Jason-1 paths. The coinciding Buoy data were selected within the 30-minute time window. The simultaneous data record of SWHT by Jason-1 and the buoys covered a range of 0 to 6 meters in the 4-year period.
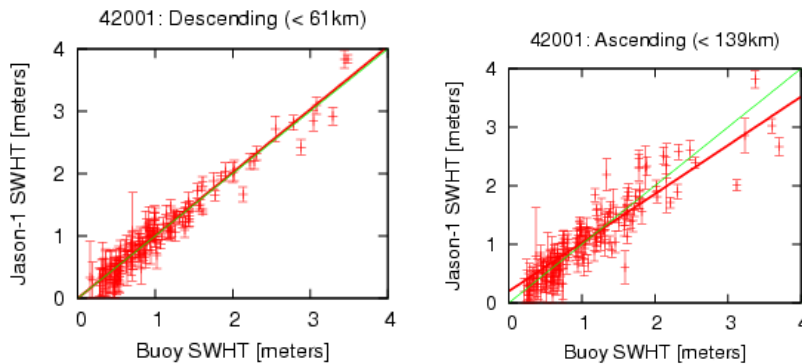

Figure 18. Example of correlation plots between buoy and Jason-1 data (ascending and descending passes averaged inside the radius shown) at one offshore (top panel) and one nearshore (bottom panel) buoy station. Green line indicates 1:1 relationship.

We found that the correlations between the buoy and the Jason-1 data are very good in general, with the rms difference of 17 - 30 centimeters (Figure 18). On average, the Jason-1 estimates were lower than the Buoy measurements by 6% (Korobkin and D'Sa 2008).

8. NCOM Mississippi-Louisiana-Texas Coastal Ocean (MsLaTex) Nowcast/Forecast System

For the modeling part, a coastal model that covers MS/LA/TX Gulf Coast has been developed on schedule. Co-PI, Dr. Ko from NRL has developed a web site to run the Mississippi-Louisiana-Texas (MsLaTeX) Coastal Ocean Nowcast/Forecast System and also provides nowcast/forecast data of model outputs which are accessed daily and displayed on the DSS website (Figure 19).
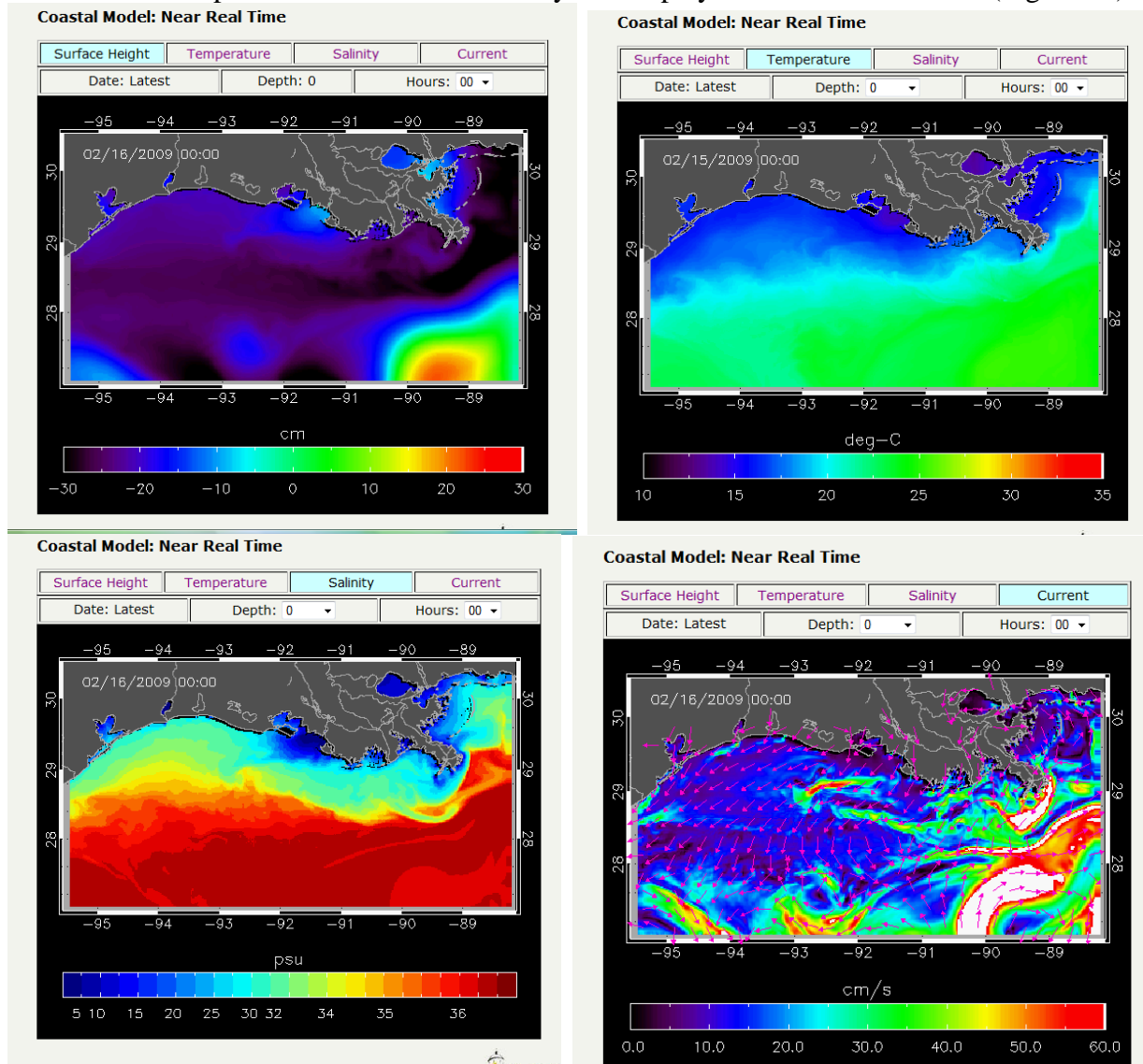

Figure 19. NCOM MsLaTex model nowcast/forecastoutputs of sea surface height, temperature, salinity and current speed/direction being served on the DSS website. Further, temperature, salinity and currents can be accessed for different depths.

The area of coverage extends from 88.2°W to 95.5° W longitude and from 27.0° to 30.5°N latitude as indicated by the surface elevation forecast (Figure 19). Other forecast output available to users include temperature, salinity and currents for various depths. Dr. Ko has also provided a 6-year long model hindcast from 2002 to 2007 to assess the model capability. The hindcast are with data assimilation of satellite remote sensing data and with synoptic surface/river forcing. The nowcast and forecast outputs from the model are now available on the DSS website as shown in Figure 19 with users having the option to select and examine the model outputs at various depths at 6 hour intervals.

8.1 NCOM MsLaTex Coastal Ocean Nowcast/Forecast System vs field data comparisons
The nested high-resolution 3-dimensional NCOM Mississippi-Louisiana-Texas (MsLaTeX) coastal circulation model (Figure 20-left panel, red grid) outputs of salinity and temperature have been compared and evaluated with water column measurements obtained from CTD casts in coastal waters influenced by the Mississippi and Atchafalaya rivers (Figure 20, inset rectangles) during research cruises undertaken in January and April 2006 and in April 2007 as part of an MMS-LSU funded project.
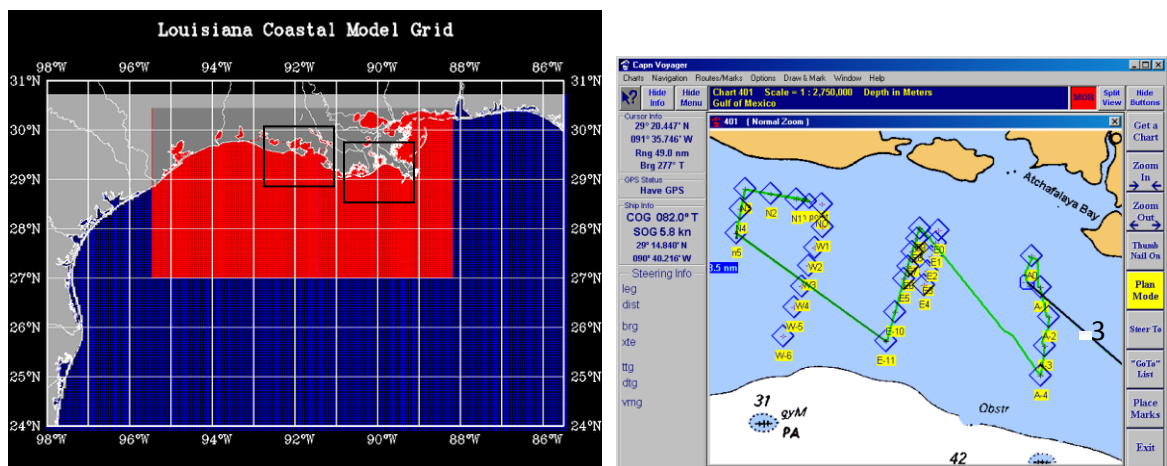

Figure 20. The spatial extent of the 3-D nested NCOM model outputs in the northern Gulf of Mexico. The rectangles (inset) indicates the Atchafalaya delta region (left rectangle) and the Mississippi delta region (right rectangle) where field data from CTD casts were compared with model outputs. (Right panel) station locations on the Atchafalaya river delta along with ship track in January and April 2006. Stations are shown with yellow labels and the ship tracks shown as green lines.

Discharge from the Atchafalaya River is approximately 1/3 that of the Mississippi River and influences large regions of western Louisiana and Texas coast. The Atchafalaya River discharges into a broad shallow shelf resulting in different effects (e.g., eutrophication) of this coastal region. There are three major shoals (Ship Shoal, Tiger Shoal and Trinity Shoal) which are being considered as important resources for sand mining. As part of MMS and LDNR funded project, a new WAVCIS monitoring station has been made operational in Tiger shoal. We show examples of CTD data acquired at two stations, one off the Atchafalaya River and the other off the Mississippi River that were used to validate model outputs. Co-located model outputs at the CTD

locations obtained within 2-hours and 1 day (average) of the CTD casts were selected and compared at depths with temperature and salinity obtained from CTD casts.

During the winter cruise (6-11 January 2006), 35 stations were occupied off the Atchafalaya Bay and a few off the Terrebone Bay to the east of the Atchafalaya Bay. The field data acquired during this cruise allowed for the model skill-assessment of water quality parameters (temperature and salinity) in shallow waters. During the spring cruise (1-5 April 2006) same stations as that of the winter cruise were occupied off the Atchafalaya Bay and enabled seasonal comparisons of water column properties. The 3-D NCOM model results for salinity, temperature, ocean currents and sea-surface height for the study region at ~2 km resolution and 3-hour intervals were obtained from NRL. Comparisons made at 10, 20 and 30 m depths indicated variable performance between model results and field data in the nearshore waters for both salinity and temperature data (Figure 21). The results of this skill assessment of the NCOM model outputs is being analyzed further for journal submission.
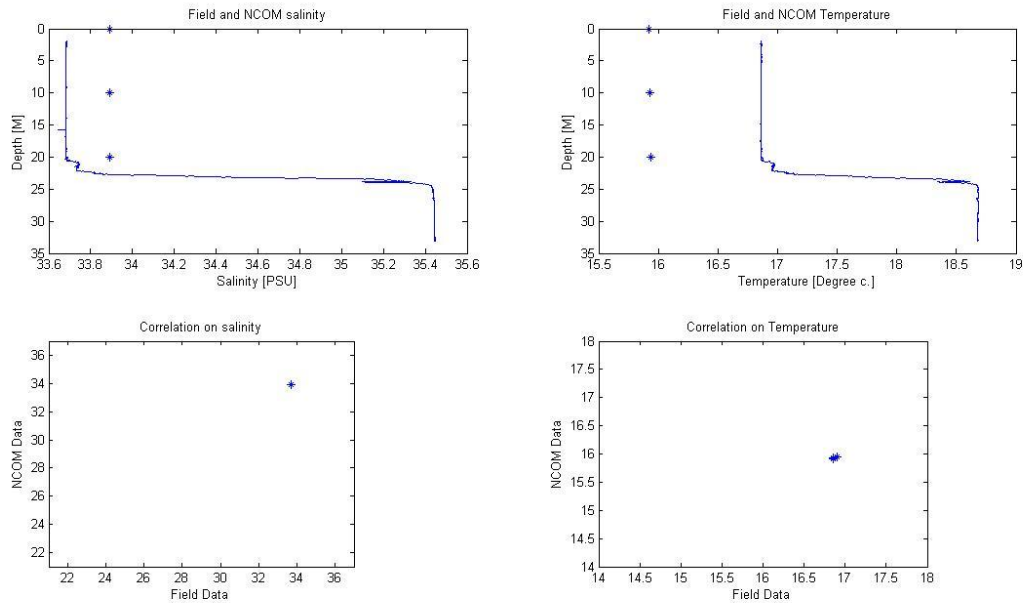

Figure 21. Vertical profile of salinity and temperature (top panel) obtained from CTD cast at station E11 in January 2006. Correlation plots of NCOM salinity and temperature at 10 and 20 m depth versus field measurements.

During April 2007, a 4-day research cruise was undertaken with 22 CTD casts that were made along four cross-shelf transects starting just west of the Mississippi birdsfoot delta with the nearshore stations being at shallow depths (e.g., station 1, 10 m depth) while the outermost stations were in the shelf and slope waters (e.g., station 5, 400 m depth). Fortran programs were written to read these files and output them in ASCII. Further, co-located model outputs at the CTD locations obtained within 2-hours of the CTD casts were selected and compared at depths with the CTD data of temperature and salinity. Comparisons at one selected station for model outputs obtained at depths (0, 10, 20, 30, 50, 70, 100 m) are shown in Figure 23. Preliminary analysis of the comparisons indicate larger differences between model results and field data in the nearshore waters while at the offshore stations model results of salinity and temperature were better correlated to in situ measurements.
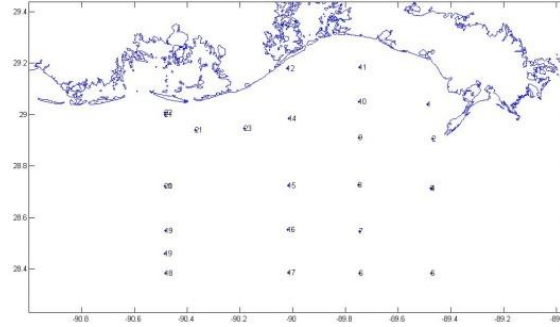
Figure 22. CTD sampling stations in the northern Gulf of Mexico occupied between 16-19 April 2007. Water column in situ salinity and temperature data are compared to the outputs of the NCOM model for the study period.
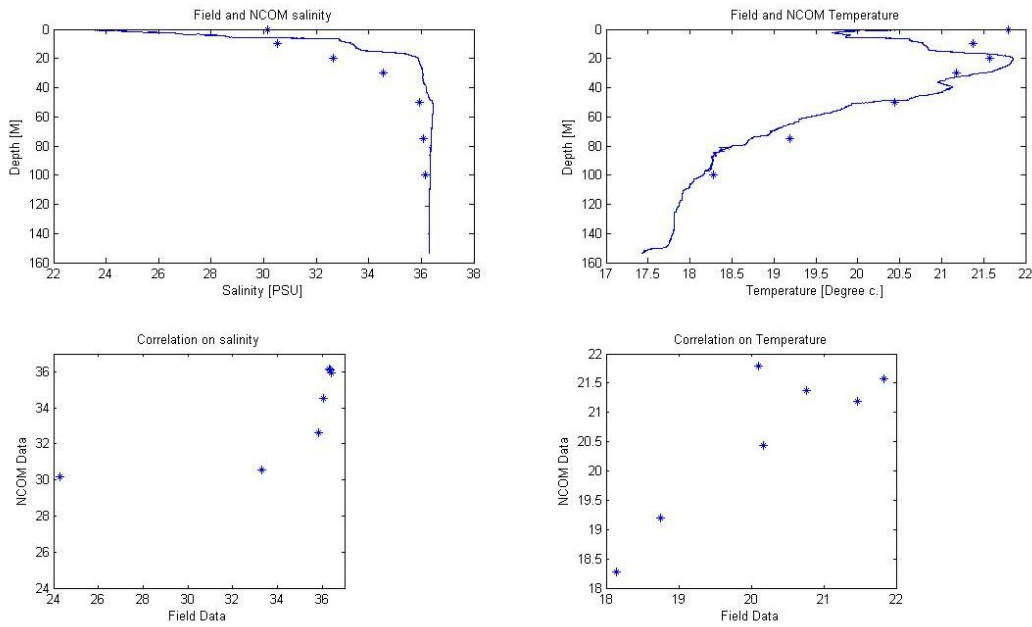

Figure 23. Vertical profiles of salinity and temperature (top panel) obtained from a CTD cast at station 3 in April 2007 off the Mississippi River. Corresponding values of salinity and temperature (+ marks) indicate NCOM model outputs at the surface, 10, 20, 30, 50, 70 and 100 m depths.

8.2 Validation of NCOM SST vs buoy and WAVCIS data

The nested NCOM Mississippi-Louisiana-Texas (MsLATeX) coastal circulation model (Figure 20; red grid) receives boundary conditions from the regional NCOM Intra-Americas Sea model that includes the Gulf of Mexico. As the performance of the nested model depends on the boundary conditions input into the nested model, we evaluated the sea surface temperature (SST) model outputs for the Gulf of Mexico by comparing SST measurements obtained at the various buoy locations (Figure 24-left panel) against the SST outputs of the regional model. Further we also examined the SST measurements obtained at the WAVCIS platform monitoring stations (Figure 24-right panel) against the model results for the period 2002-2006 averaged over a 5-day period.
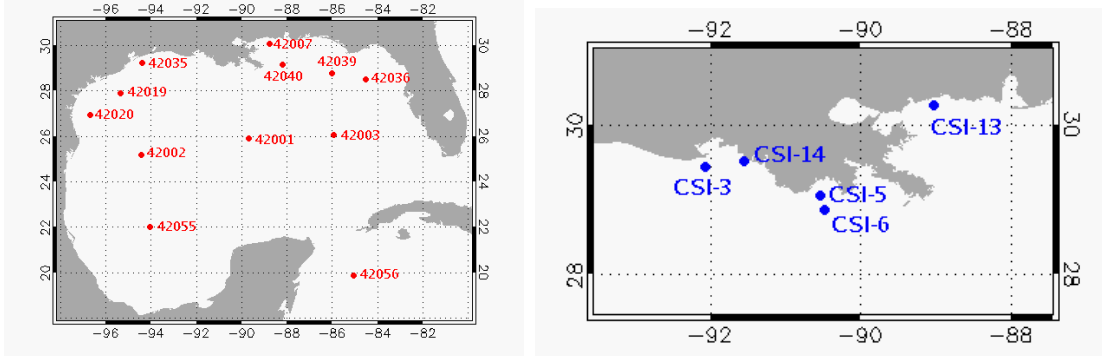
Figure 24. Location of NDBC buoys in the Gulf of Mexico used in the study (left panel). Meteorological (e.g., winds) and oceanographic (e.g., sea surface temperature) parameters are readily available from the NOAA-NDBC website. (Right panel) Location of the WAVCIS platform monitoring stations located along the Louisiana coast.

We used an extensive set of time-series buoy and WAVCIS station observations for the validation. A comparison of SST between NCOM and buoy SST indicates that at the offshore locations the model has a root-mean-square difference (RMSD) between 0.50 and 0.75 for most of the buoys located in the Gulf except for the two near-shore buoys (43007 and 42035) where the differences are ~1° C. However, differences were much larger for the WAVCIS stations (Table 1). Another statistical metrics used include the calculation of the dimensionless skill scores (SS). The model provided a reasonable prediction of SST (Table 1) with SS of one indicating perfect SST simulation. Overall we observed better comparisons for the offshore buoy locations than those located close to the coast. In the case of WAVCIS monitoring stations, the correlations were higher for the more offshore stations (e.g., CSI-6) than the ones closest to the coast (CSI-3 and CSI-5). Statistical metrics were derived from these comparisons for each of the buoy locations (Table 1).
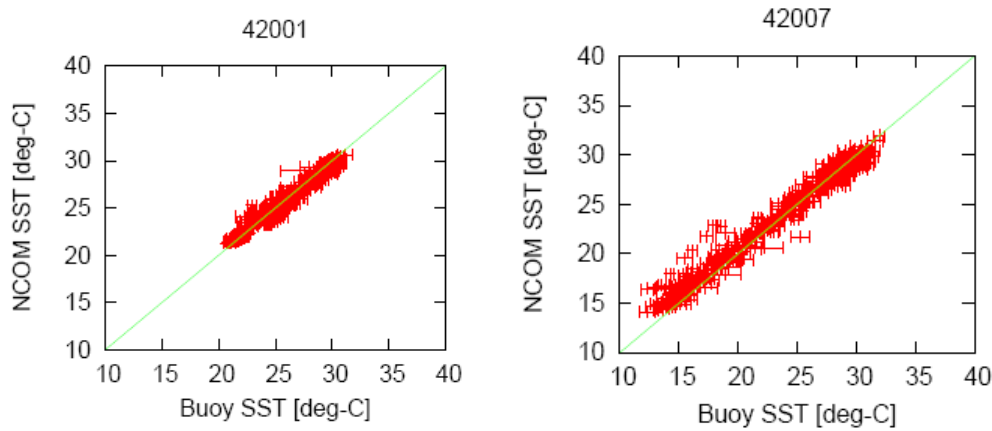

Figure 25. Correlation plots of 5-day averaged SST measured at selected NDBC buoy stations and the model calculations.
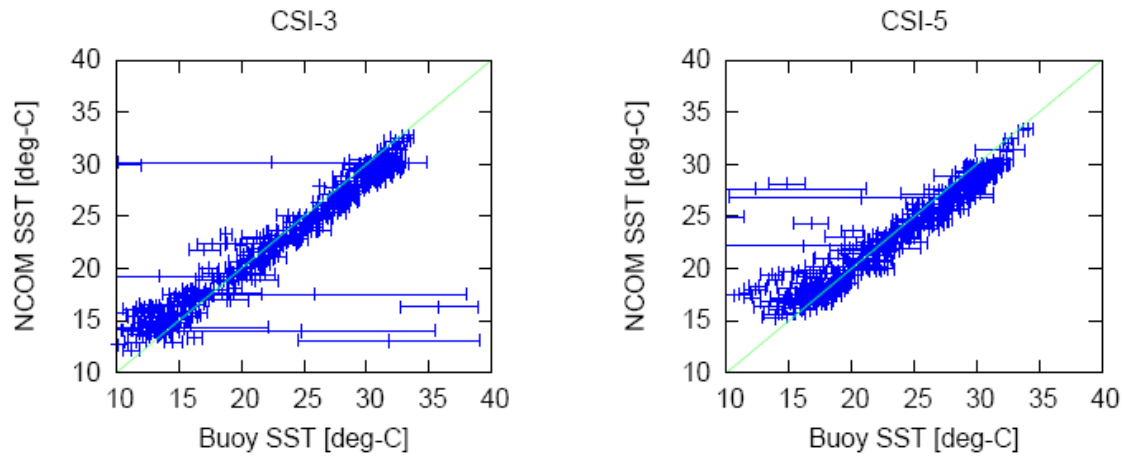
Figure 26. Correlation plots of 5-day averaged SST measured at the WAVCIS stations (CSI-3 and CSI-5) and corresponding NCOM model calculations for the period 2002-2006.

Station ID	N	ME	RMSD	R	SS
42001	364	-0.011	0.60	0.98	0.95
42002	364	-0.024	0.51	0.99	0.97
42003	290	-0.020	0.75	0.95	0.88
42007	338	0.043	1.17	0.99	0.96
42019	352	0.005	0.66	0.98	0.97
42020	364	0.028	0.65	0.99	0.97
42035	364	0.036	0.92	0.99	0.98
42036	358	0.007	0.64	0.99	0.98
42039	353	-0.003	0.74	0.98	0.96
42040	333	0.015	0.68	0.99	0.97
42055	118	-0.056	0.65	0.99	0.91
42056	101	-0.039	0.50	0.97	0.79
csi03	338	0.084	5.52	0.76	0.56
csi05	318	0.017	2.92	0.89	0.78
csi06	246	-0.092	2.16	0.93	0.83
csi13	224	0.046	1.86	0.98	0.92

Table 1. Statistical metrics for each of the NDBC buoy and WAVCIS stations located in the Gulf of Mexico. Station ID corresponds to the location of the buoy and WAVCIS stations, N – the number of data points, ME – mean error, RMSD – root mean square difference, R – correlation coefficient, and SS - the dimensionless skill score.

8.3 NCOM Coastal Ocean Nowcast/Forecast System and comparison of model SSHA for the Gulf of Mexico against Jason-1 data

The Intra-Americas Sea Ocean Nowcast/Forecast System (IASNFS) which includes the whole Gulf of Mexico, the Caribbean Sea, the Straits of Florida and parts of western north Atlantic (Figure 27) provides the boundary conditions to the MsLaTeX coastal circulation model. During the nowcast, the ocean model continuously assimilates the three-dimensional ocean temperature/salinity analyses produced by a statistical data analysis model, the Modular Ocean Data Assimilation System (MODAS). Real-time satellite altimeter (GFO, Jason-1, ERS-2 sea surface height anomaly data as well as AVHRR sea surface temperature data are used by MODAS to generate the three-dimensional temperature and salinity analyses. In the Gulf of Mexico, an important consideration in assessing the performance of a numerical model is its accuracy in representing the observable features of the Loop Currents (LC) and its eddy field. As part of our assessment of the MsLaTeX NCOM model we have examined the IASNFS NCOM model results of sea surface height anomalies (SSHA) against Jason-1 satellite altimetry for the Gulf of Mexico (D'Sa et al. 2008).
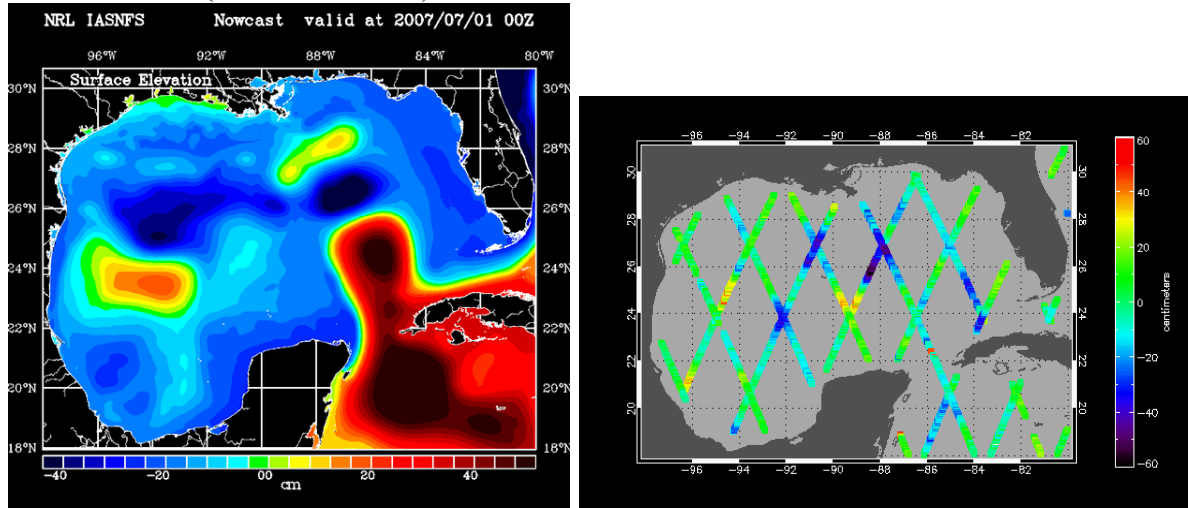

Figure 27. (Left panel) Model sea surface height (cm) output of the IASNFS NCOM model for the Gulf of Mexico. Output of this model is used as boundary condition for the MsLaTeX coastal model. (Right panel) Jason-1 along-track differences of SSHA between Jason and the NCOM model.

The SSHA data from Jason-1 were acquired from Physical Oceanography Distributed Active Archive Center (PO.DAAC) Jet Propulsion Laboratory and processed for the Gulf of Mexico region covering the period from 15th January 2002 to December 2006. The SSHA values represent the difference between the best estimate of the sea surface height and a mean sea surface. The sea surface height was corrected for atmospheric effects, effects due to surface conditions and other contributions such as ocean tides, pole tide, and inverse barometer. SSHA values are gridded to reference tracks which have standard latitude and longitude locations and are same for every cycle. A cycle contains up to 254 passes and represents a collection of data where the ground track of the Jason-1 satellite repeats itself approximately every 10 days. Data along all the tracks over the 10-day period were used to obtain SSHA maps of the Gulf of Mexico region using simple interpolation. Model SSH forecasts for the period 2002 to 2006 were used in this study with 5-day averages of model results being used for comparisons with the

Jason-1 altimeter data. Model SSH data were averaged over the entire period and subtracted from the 5-day average SSH fields to derive model SSHA or variations. Along-track Jason-1 SSHA obtained each 10-day window were compared to the closest 5-day model SSHA along the satellite tracks. An examination of RMS differences for all cycles in 2002 for the different tracks in the Gulf suggest both temporal and spatial differences in SSHA (Figure 28), with the lowest differences observed along nearshore track in the western GOM (Figure 16-left panel) and the largest RMS difference was measured along track 91 which transects the western part of the Gulf between the Yucatan peninsula and the Florida Panhandle. This track transects the most active region of the Gulf with highest variability in SSHA associated with LC instability and eddy separation.
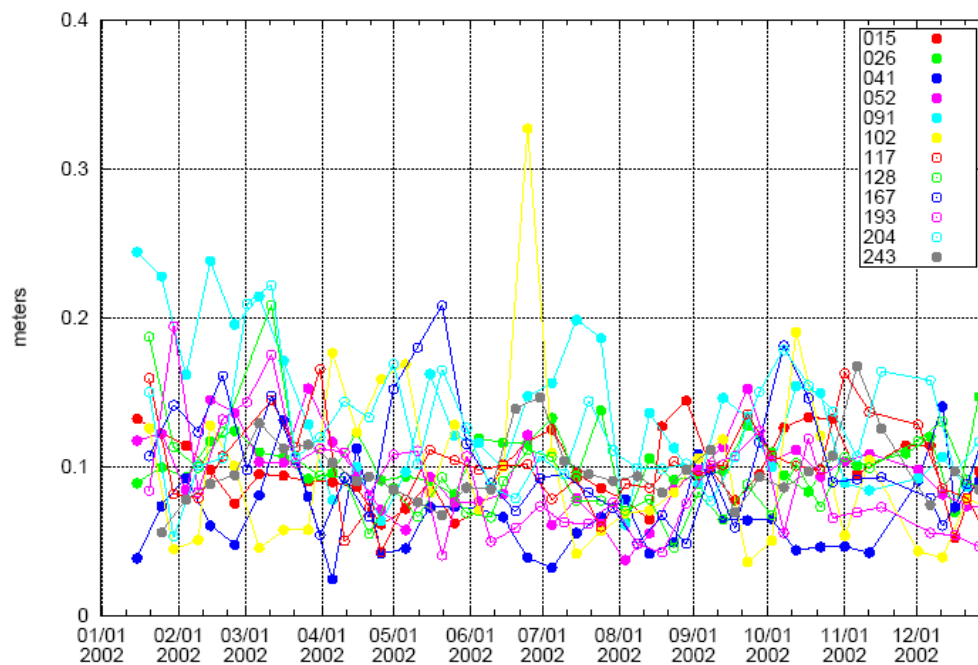

Figure 28. SSHA root-mean-square (RMS) difference between NCOM model output and Jason-1 tracks in the Gulf of Mexico for the year 2002.

9. Performance of Satellite Data and Model Outputs During an Energetic Cold Front
Energetic meteorological events such as frontal passages, storms and hurricanes have strong environmental impacts in the coastal regions in the northern Gulf of Mexico. It also strongly influences biogeochemical processes such as the suspended particulate matter (sediments, organic) fluxes. As part of this study we have examined a frontal passage during the period 21-28 March 2005 using satellite and model data (D'Sa and Ko 2008 - Sensors). Satellite remote sensing data used include the new 12.5 km QuikSCAT wind speed/direction and SST from MODIS and ocean color data. Model outputs used in this study include SST, sea surface height and currents.

Results of this study indicated strong influence of the wind field associated with the frontal passage on the coastal sea level, currents and the suspended particulate matter (D'Sa and Ko 2008). Comparisons of model sea level variations with tide gauge measurements in Galveston-

Texas, Grand Isle-Louisiana and Waveland-Mississippi indicated model results to generally correlate well with tide gauge measurements (Figure 29). However larger differences can be observed between model predictions and tide gauge measurements at Galveston-Texas than at Waveland-Mississippi. A large drop in sea level or coastal set down is observed all along the coast following the strong frontal passage of 27 March 2005. The differences are pronounced following the frontal passage where tide gauge measurements were observed to indicate a drop in sea levels greater than 80 cm at Galveston. However, model predictions underestimated water level set down suggesting need for improvements in model outputs during energetic frontal passages.
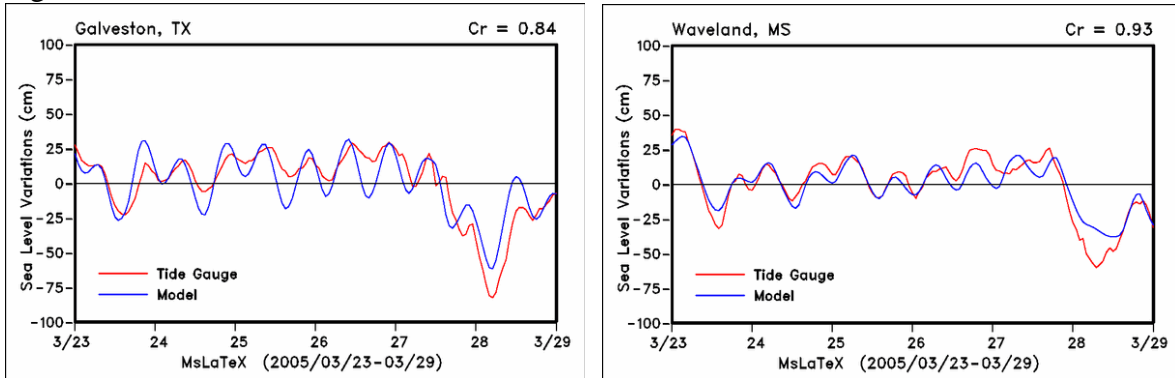

Figure 29. Comparison of sea level variations from the high resolution MsLaTeX coastal model and tide gauge measurements obtained in Galveston-Texas (left panel) and Waveland-Mississippi (right panel).

10. Performance of Satellite Data and Model Outputs during Hurricane Rita - September 2005.

Hurricane Rita was one of the many energetic meteorological events that impacted the northern Gulf of Mexico in 2005. Hurricane Rita entered the Gulf of Mexico on 21 September and made landfall along the Louisiana-Texas border on 24 September 2005 (Figure 30-left panel; arrows denote the hurricane path). .As the hurricane traversed over the warm Loop Current waters in the central Gulf of Mexico it intensified into a Category 5 hurricane and then decreased to a Category 3 hurricane as it transitioned over the northern Gulf.

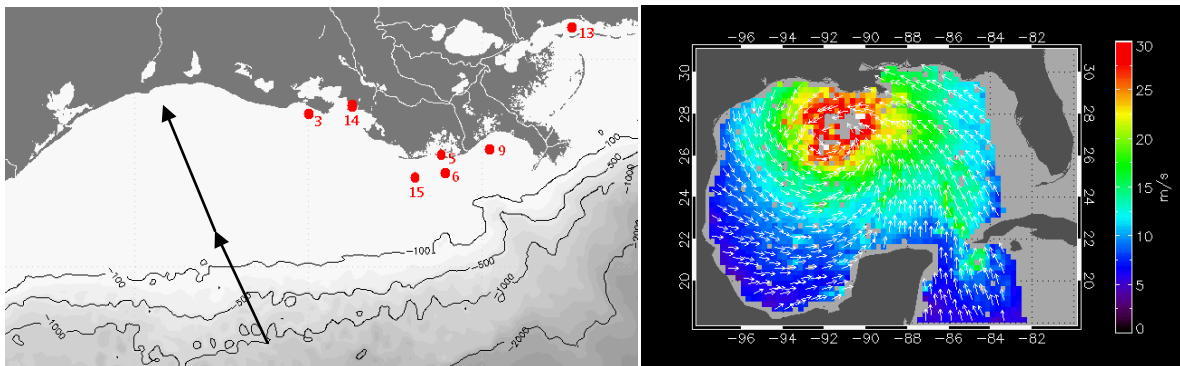Figure 30. (Left panel) Study area in the northern Gulf of Mexico that includes the coastal region comprising the states of Mississippi, Louisiana and part of Texas. The location of the WAVCIS monitoring stations (red circles) and the path of Hurricane Rita (brown circles, arrows) in the northern Gulf of Mexico are shown. (Right panel) QuikSCAT wind speed and direction during hurricane Rita on 23rd September 2005.

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The latest level 2B 12.5 km resolution QuikSCAT wind data obtained on 23 September 2005 (Figure 30-right panel) clearly revealed the intense cyclonic activity at the center of the hurricane and its northwest movement towards the Louisiana-Texas border. The 1800 km wide swath obtained from QuikSCAT measurements also provided a synoptic view of the wind field (speed and direction) over the entire storm system. The cyclonic wind field covered the whole of the Gulf of Mexico with gradients of decreasing wind speed observed from the hurricane center where a few pixels recorded wind speeds in excess of 30 ms^{-1} while winds in excess of 15 m s^{-1} extended to over 400 km from the center of the hurricane. A large number of wind pixels (grey) represent invalid data as the accuracy of QuikSCAT wind retrievals are affected by land, rain or very high winds. Model outputs and MODIS SST were also examined during this event (D'Sa et el. 2008 – SPIE Proceedings).

11. Installation of MapServer and test display of Landsat high resolution maps.
We have successfully installed and tested the open source MapServer (leading web mapping package) in the Gulf Coast Information website http://gulf-coast.lsu.edu/GIS.html. MapServer is an Open Source development environment for building spatially-enabled internet applications and is especially good at rendering spatial data (maps, images and vector data). MapServer was originally developed by the University of Minnesota ForNet project in collaboration with NASA. With the successful installation of the MapServer we have incorporated a few, and plan to add more high-resolution Landsat imagery for coastal regions of Mississippi, Louisiana and Texas.
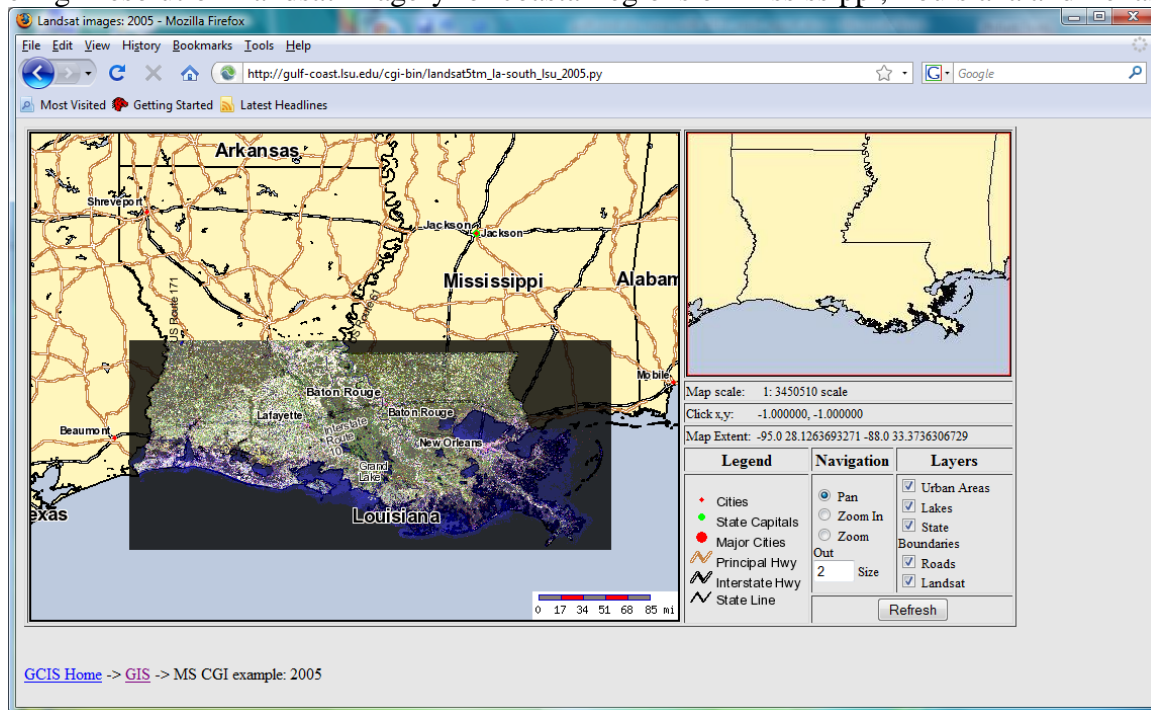

Figure 31. A screen copy of the MapServer interface being developed to enhance the capability of the decision support system. Shown above is a high resolution Landsat image of a section of coastal Louisiana that was selected for display on the MapServer interface.

As part of our effort to develop a GIS interface for serving remote sensing data we also installed and tested the Google Earth server on the Gulf Coast Information website. (http://gulf-coast.lsu.edu/GIS.html). Landsat imagery of coastal Louisiana were converted to KML, a file

format required to display geographic data in a Earth browser such as Google Earth. However we plan only a limited application of this interface as a more extensive application requires the purchase and subscription on a long-term basis of the Google software. Due to this limitation we have decided to use the Open Source MapServer software to implement the GIS component.
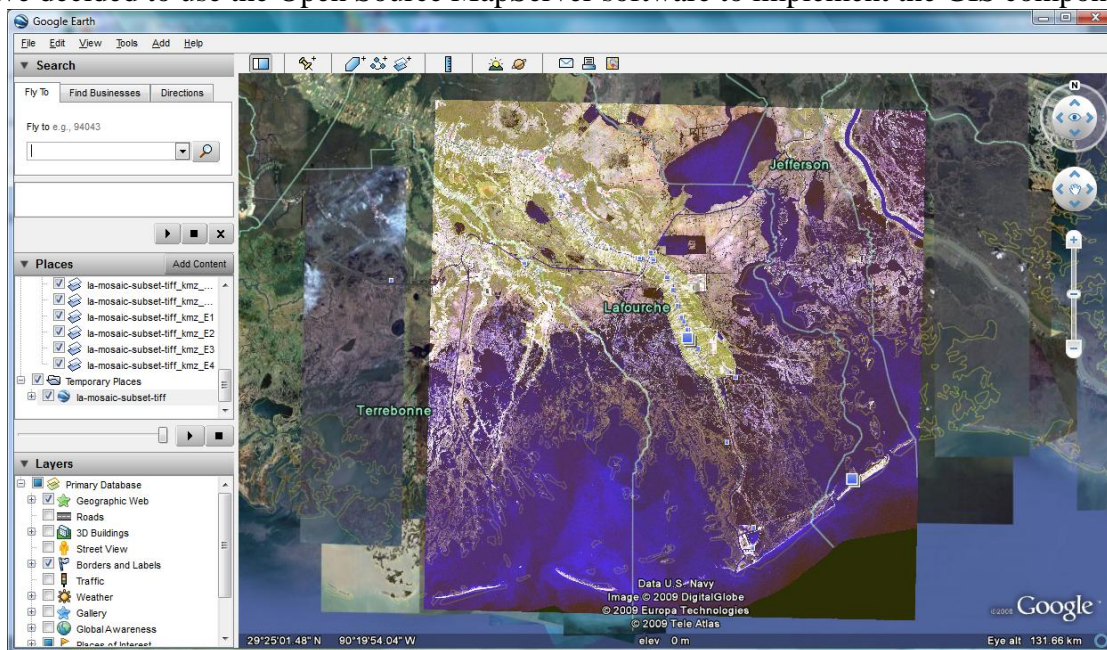

Figure 32. Display of Landsat imagery on the Google Earth server on the DSS website.

12. Computing facilities

 Two high performance Linux computers are now operational – one as a web server and the other for processing of data being acquired from various satellites. Two Terrabytes of additional hard disk memory was installed for ingest and processing of NASA data and products. Additional software packages were purchased and installed on the Linux computer. Opendap, and FTP servers are now operational through our web servers that will enable users to remotely access NASA derived data and products. Data access for Jason-1 products (along-track/mapped SSHA in the Gulf of Mexico region) and localized (study area) L2 high resolution (12.5 km) QuikSCAT data in NetCDF format are available through Opendap server. Also their images (in GIF format) and ASCII outputs are being posted through the FTP server (**http://gulf-coast.lsu.edu**).

13. Work on related projects in the northern Gulf of Mexico

As part of MMS funded project we have acquired field data in the northern Gulf of Mexico from 6 – 9 April 2008. The sampling stations consisted of four cross-shelf transects west of the Mississippi river delta that extended from near-shore to offshore waters. About 22 CTD stations were occupied during the three and half day cruise with discrete water samples being acquired at three depths (surface, mid-depth and bottom) and samples processed for HPLC chlorophyll, colored dissolved organic matter (CDOM) and suspended particulate matter (SPM). Surface measurements of these parameters will be used for validation of ocean color remote sensing data products obtained from MODIS satellite sensor. CTD water-column data acquired during cruises

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in the northern Gulf of Mexico are being used for comparing with the NCOM model simulation of salinity and temperature data allowing for skill-assessment of the model.

Also, participation and field data collection of in three research cruises in 2007 as part of an MMS and the Louisiana Department of Natural Resources funded project titled "Environmental investigations of the long-term use of Ship shoal sand resources for large-scale beach and coastal restoration in Louisiana" has provided baseline data to assess performance of ocean color products such as CDOM in shoal dominated coastal regions which provide important offshore sand resources for coastal restoration.

14. PI project management and supervision of graduate students and a Research Associate (Dr. Mitsuko Korobkin) presently working on the project. PI meeting with project collaborators at LSU and NRL, Stennis Space Center, MS. In addition, PI meeting with users such as MMS and LDNR advisors.

15. List of publications in peer reviewed journals

Sharma, N., and E. J. D'Sa. 2008. Assessment and analysis of QuikSCAT vector wind products for the Gulf of Mexico: A long-term and hurricane analysis. *Sensors*, 8:1927-1949. (open source: http://www.mdpi.org/sensors/papers/s8031927.pdf)

D'Sa, E. J. 2008. Colored dissolved organic matter in coastal waters influenced by the Atchafalaya River, USA: effects of an algal bloom. 2, 023502, *Journal of Applied Remote Sensing*, doi:10.1117/1.2838253.

D'Sa, E. J. and D. S. Ko. 2008. Short-term influences on suspended particulate matter distribution in the northern Gulf of Mexico: satellite and model observations. *Sensors,* 8, 4249-4264, DOI: 10.3390/s8074249. (Special Issue on *Ocean Remote Sensing*).

Naik, P., E. J. D'Sa, M. Grippo, R. Condrey and J. Fleeger. (2009-to be submitted) Absorption properties of shoal dominated waters in the Atchafalaya shelf, Louisiana, USA. *Estuarine and Coastal Shelf Science*.

16. Conference Proceedings

Korobkin, M. and E. J. D'Sa 2008. Significant Wave Height in the Gulf of Mexico: Validation of Jason-1 measurement against buoy data. *12th Conference on Integrated Observing and Assimilation Systems for Atmosphere, Ocean and Land Surface (IOAS-AOLS)*, 20-24 January, New Orleans, LA.

D'Sa, E. J., D. S. Ko, and M. Korobkin 2008. Comparison of sea surface heights derived from the navy coastal ocean model with satellite altimetry in the Gulf of Mexico,. *12th Conference on Integrated Observing and Assimilation Systems for Atmosphere, Ocean and Land Surface (IOAS-AOLS)*, 20-24 January, New Orleans, LA.

D'Sa, E. J., M. Korobkin, N. Walker, and G. Stone. 2008. Using NASA remote sensing data for coastal monitoring in the northern Gulf of Mexico: a case study. In: *Sensors, Systems, and Next-Generation Satellites XII* (Eds. R. Meynart, S. Neeck, H. Shimoda, and S. Habib) Proc. of SPIE Vol. 7106, 71061R-1 (Presentation and Proceedings paper).

D'Sa, E. J. and M. Korobkin. 2008. Colored dissolved organic matter in the northern Gulf of Mexico using ocean color: seasonal trends in 2005. In: *Remote Sensing of the Ocean, Sea Ice, and Large Water Regions* (Eds. C. Bostater, S. Mertikas, X. Neyt and M. Velez-Reyes). Proc. of SPIE Vol. 7105, 710505-1 (Presentation and Proceedings paper).

Naik, P. and E. J. D'Sa. 2008. Absorption properties in shoal dominated regions of the Atchafalaya shelf, Louisiana, USA. MTS/IEEE Oceans 2008 Conference (Presentation and proceedings paper).

D'Sa, E. J., P. Naik and E. Swenson. 2008. Optical properties of chromophoric dissolved organic matter along a transect in the Barataria Bay, Louisiana. MTS/Oceans 2008 Conference (Presentation and proceedings paper).

E. J. D'Sa. 2008. CDOM optical variability and distribution in the northern Gulf of Mexico from field and ocean color data. Ocean Optics OOXIX, Barga, Italy, 6-10 October 2008 (Poster).

17. Presentations/Workshops/Seminars/Posters

D'Sa E. J., M. Korobkin, and D. S. Ko. "Assessment of NASA remote sensing products for assimilation into a gulf coast monitoring system: preliminary results." *AGU 2008 Ocean Sciences Meeting*, Orlando, Florida, 3-6 March 2008,

D'Sa, E. J. "An assessment of remote sensing data for integration into a Gulf coast monitoring system", Invited Seminar presented at the *Institute of Marine Coastal Sciences, Rutgers University*, New Jersey, 28 January, 2008.

PI participation and poster presentation titled "Integrating satellite and model data for event monitoring in the northern Gulf of Mexico," at the *2008 NASA Carbon Cycle and Ecosystem Joint Science Workshop*. Adelphi, Maryland, 28-30 April, 2008.

PI participation and poster presentation titled "Short-term physical influences on CDOM in the northern Gulf of Mexico" at the *Scoping Workshop on Terrestrial and Coastal Carbon Fluxes in the Gulf of Mexico*, St. Petersburg, Florida, 6-8 May, 2008.

Naik, P. "Absorption properties in shoal dominated regions of the Atchafalaya shelf". *2008 Graduate Student Research Symposium*, Louisiana State University, Baton Rouge, LA.

D'Sa, E. J., D. S. Ko, M. Korobkin, N. Walker, G. Stone, D. Braud. A Gulf Coast monitoring and hazards decision support tool – Enhancements using NASA Earth Science products, data and models. *In Grand Challenges in Coastal Resiliency I – A Coastal Sustainability Agenda (CSA) Grand Challenge Workshop*, Louisiana State University, 20-21 January, 2009.

D'Sa, E. J., E. J., D. S. Ko, M. Korobkin, N. Walker, G. Stone. Monitoring water quality in waters influenced by the Mississippi-Atchafalaya river system using NASA Earth Science products, data and models. Selected for presentation at the *Gulf of Mexico Alliance Nutrient Criteria Research Framework Workshop*, 10-12 March, 2009, New Orleans, LA.

Graduate Students and Research Associate involvement
Saurabh Singh, M.S., Electrical Engineering Department, LSU (part-time, started October 2008)
Shatrughan Singh, M.S. student, Coastal Studies Institute, LSU, started January 2007
Puneeta Naik, Ph.D. student, Coastal Studies Institute, LSU, started January 2007
Rupesh Kumar, B.S., IIT, Kharagpur, Summer Internship.
Mitsuko Korobkin, Ph.D., Research Associate.